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ANALYSES OF MILK.

	Cow's Milk.	Human Milk.	Meigs' Artificial Food.
Water,	87.012	87.163	87.639
Fat, ...	4.209	4.283	4.765
Casein, . .	3.252	1.046	1.115
Sugar, . . .	5.000	7.407	6.264
Salts, .	.527	.101	.217
	100.000	100.000	100.000

It is to be noticed that the water and fat are nearly the same in cow's and human milk; the greatest difference occurs in the proportions of casein and sugar. In the artificial food this difference is overcome by dilution with water and the addition of sugar and fat (cream).

The conviction of the great importance of the subject of feeding in early infancy impels the production of this brief essay. When for any reason a young infant cannot be nursed by the mother, and the number of such infants is very great, the opening question of the drama of life is how it shall be fed, and upon this question depend its life and health. The ignorance which exists in regard to a subject that, to a certain extent, is so simple, is disheartening, especially as knowledge has so

far progressed that certain principles are fixed, and that, although this knowledge is now available for the use of everyone, it often is not utilized. Could any field in medicine make fairer promises to those who will interest themselves in it than one which offers the opportunity to prevent rather than to cure disease?

It is extraordinary with what confidence inexperienced persons approach the question of the artificial feeding of infants. Physicians, mothers, and nurses alike, if they have never learned anything of the difficulties of rearing infants by hand, are generally disposed to think the matter very simple and are quite ready to make the trial. The fact of being without any fixed principles in regard to what may be required deters few. To attain any great success in artificial feeding it is necessary to establish principles upon which may be rested a system to be pursued in ordinary instances. No method of attaining this end has ever yet been suggested, except the simple and obvious one of trying to obtain a food as nearly as possible like human milk, which is beyond doubt the best for young infants.

More than fourteen years ago (February 22, 1882) I read before the Philadelphia County Medical Society a paper upon "Milk Analysis"[1] in which the following statement was made: "My own analyses prove that human milk never contains more than from seven-tenths of one to one and a half per cent. of casein,[2] and about seven per cent. of sugar." In December, 1893, I read

[1] *Transactions of the Philadelphia County Medical Society*, 1882, and *The Philadelphia Medical Times*, July 1, 1882.

[2] Casein is the cheesy element of milk; it forms the curd, and it is the large proportion of casein in cow's milk that makes it, when undiluted, difficult for babies to digest.

a second paper entitled, "Proof that Human Milk contains only about one per cent. of Casein; with Remarks upon Infant Feeding." In this second paper the main statement of the title was shown to be correct. The train of argument brought forward at that time seemed conclusive, and nothing has since been discovered to cast any doubt upon it. It is unnecessary to reiterate all that was then said, but it may be repeated that human milk never contains more than one per cent. of casein, and in this fact lies the key to an understanding of what must be done in preparing an artificial food.

The principal argument used to prove that the proportion of casein is always so small was that, as there is no difference of view among analysts as to the proportions of any of the proximate principles of human milk except the casein and sugar, all chemists having reached the same conclusion in regard to the quantities of water, fat, and inorganic material, the casein and sugar were therefore not really separated from each other, and that sugar was on the one hand sometimes classed as casein and on the other hand casein was classed as sugar. At the same time it was pointed out that Wanklyn had shown that milk exhibits great constancy of composition, that the milk of an animal has probably very much the same constancy of composition as the blood, and, further, that this constancy of composition is a cardinal fact in milk analysis; for if milk were variable in strength, as is urine, chemical analysis would be of little use in establishing facts which it is commonly considered to prove.[1]

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[1] It is of course well known that the quantity of fat varies within limits.

It is astonishing what strange and seemingly contradictory statements are made, even by those looked upon as authorities, in regard to the composition of milk, so far as concerns the amounts of casein and sugar. Rotch, in his recent book on Pediatrics, after stating that normal human milk contains 1.50 per cent. of casein, or, as he calls it, "proteids," and seven per cent. of sugar, gives a number of analyses in which the proportions of these two component parts vary very largely, in one case the amount of casein being so great as 4.74 per cent. So high an estimate of the casein as this must always be due to error, the consequence of failure to separate the casein and sugar. This likelihood of confusion of sugar with casein was also adverted to in one of the papers above mentioned, and at the same time reasons were given for believing that the copper test for milk-sugar is not reliable when applied to milk analysis. This test is the one employed by most analysts to estimate the sugar, and there is good reason to believe it to be entirely unreliable for the analysis of milk. The keynote to the successful feeding of infants lies in an appreciation of the fact that human milk contains only about one per cent. of casein, and that if cow's milk, which contains three per cent., is to be used as the basis of the food, it must first be fittingly diluted, and then other changes be made to bring the various constituent parts to be nearly the same as those in human milk.

The food recommended in the paper read fourteen years ago, I have never seen any reason to change in any of its essential particulars. This mixture, which by actual analysis has been proved to be of very nearly the same composition as human milk, is most easily prepared as follows:—

There must be obtained a quart of good fresh milk; not too rich, and not poor, average milk is best; this is placed in a high pitcher or other vessel and is allowed to stand in a cool place for three hours. The upper half or pint is then poured off, care being taken not to shake the vessel, and this upper pint, of weak cream, is to be kept for the use of the infant. The other half of the quart, which is skimmed milk, may be sent to the kitchen. There must also be made a solution of milk-sugar of the proportion of 18 drachms to the pint of water. It is best to weigh the sugar, or to have an apothecary prepare a number of packages each containing 18 drachms of milk-sugar. A wide-mouthed pint bottle should be provided into which may be put 18 drachms of milk-sugar and one pint of water. By having a wide-mouthed pint bottle there is no need for any other measure, and the sugar in bulk is more easily put into such a bottle than into an ordinary one with a narrow neck. This sugar-water must be kept in a place that is not too hot, nor should it be kept in a refrigerator, as great cold precipitates the sugar, and heat causes it to ferment. In hot weather the sugar solution should be examined from time to time, and if it sours must be thrown out and prepared afresh. Having the milk and the sugar-water ready, only one other ingredient is required, lime-water.

The lime-water of course can easily be purchased, but all mothers should be instructed how to make the lime-water for themselves, if they are to feed an infant upon my food for any length of time. Three or four tablespoonfuls of clean, fresh-slaked lime should be put into a quart bottle, and the bottle filled with clean water and shaken. After the expiration of an hour the lime will be found to have settled to the bottom of the bottle,

and the water above to be perfectly clear. It is of course well-known to chemists, but is not always remembered as it should be by physicians, that water will only hold a fixed amount of lime in solution, and this amount is very minute. The clear water is good lime-water, which should be poured off, without shaking, through two or three thicknesses of muslin into another clean bottle; it is then ready for use. Such a bottle containing the lime may be refilled with water as often as it has been emptied, and almost indefinitely will the lime make good lime-water.

When the food is to be used there must be taken of the weak cream (the upper pint which was poured off and retained) three tablespoonfuls, of the lime-water two tablespoonfuls, and of the sugar-water three tablespoonfuls. These substances together are placed in the feeding-bottle and warmed to the degree that may be desirable; the food is then ready for use. It is rather unusual for an infant to be entirely hand-fed from birth, that is, never having been put to the breast; for in most instances after the birth of an infant there is a short period of uncertainty, during which it is being decided what shall be done.

Regarding the period after birth when the feeding shall begin, it is best to imitate nature in this particular as well as in the composition of the food. During the first forty-eight hours after birth women secrete very little milk and an infant put to the breast of its mother gets only a little colostrum. Therefore, if it is possible, it is safest to allow an infant to suckle during the first forty-eight hours, even if it is to be brought up on artificial food and if the mother appears to have almost nothing for it. If this procedure is impossible, nothing should

be given the infant until it is two days old, except a few teaspoonfuls of sugar-water, which may be prepared by dissolving an ordinary lump of sugar in a tumblerful of water. This sweetened water, which makes a drink rather than a food, can be used to pacify the infant until it is two days old, when, under strictly natural conditions, it first gets any amount of nourishment. At the end of two days food must be given.

A good method is to prepare two ounces of the food at a time, and to give of this from a nursing-bottle as much every two hours as the infant will take. Judgment must be exercised that only as much of the food is given as is really wanted, just as should be done when an infant nurses. A young infant should not be urged to take too much, especially during very early life, when the powers of digestion may easily be overtaxed and great injury be done. Two ounces of the food may be made by taking six teaspoonfuls (drachms) of the weak cream, whose preparation has already been described, four teaspoonfuls of lime-water, and six teaspoonfuls of sugar-water.

Originally my food was recommended to be made by taking two parts of cream, one of milk, two of lime-water, and three of the sugar-water. The only objection to this formula is that cream obtained from milkmen has already been kept for at least twelve hours and generally for a longer period. It is therefore liable to turn sour and has had greater opportunity to become impure than milk. For this reason the method was adopted of setting a quart of fresh milk for three hours and then pouring off the upper pint, which is a weak cream and from the use of which a food is produced of the same strength as if two parts of ordinary cream and

one of milk were used. This fact has been ascertained by analysis.

An infant two days old should take only about half an ounce of nourishment at a feeding, and it will take this amount seven or eight times each day; if it sleeps naturally, it is not possible to feed every two hours, which would make twelve feedings per day. The proper quantity, therefore, for a two-days-old child is between three and four ounces. The daily amount required will gradually increase, until at the end of twenty-one days it will be found that the infant is taking about two and a half ounces at a time, and still about seven or eight feedings in each day, making a total of from 17 to 20 ounces. When the sixth week has been reached, about four ounces will be required at a time, making a total quantity of nearly 32 ounces.

These estimates of the amount of food for infants during the first few weeks of life may possibly be a little too high, but they will not be found to vary much from what babies should have at that period of life. There is great difference in the appetites of infants, just as with those of older persons, and generally a baby should not be urged to take more than it wants unless it is very indifferent to food and takes much less than the quantities above mentioned. In case insufficient food is taken, a judicious nurse, by the exercise of patience and a little coaxing, can induce most infants to take what is needful.

The reason for ordering two ounces of food to be prepared for a two-days-old infant, which should take only half an ounce at a time, is because the appetite and need for food will very soon increase, but almost imperceptibly, after the first few days. If a less quantity was

made ready for each feeding the baby would soon be getting a deficient amount; therefore it is better to have at first too much and let the excess be thrown out than to take the risk of giving too little. After the first six weeks it will be found there is a natural desire for an increased quantity of food, just as there was in the earlier period. The amount taken by a healthy infant will increase to six or eight ounces at each feeding, but generally the number of daily feedings will grow less. A very young infant will require to be fed seven or eight times a day, but one of from four to six months will only take nourishment from five to seven times a day. The quantity taken will be found to vary between somewhat less than two pints and three pints. The food, therefore, is to be increased in amount, but continued always of the same strength until an infant is from six to nine months of age.

Most books giving directions for artificial feeding recommend that the food be increased in strength every few weeks from the time an infant is a few days old until it is old enough to take pure cow's milk. The reason for this recommendation is difficult to understand, and it seems a cardinal error. For infants nursed by their own mothers nothing of the sort is accomplished. Although some milk analysts have tried to show that human milk changes in composition as the weeks and months go by, not one of them has ever succeeded in bringing forward sufficient reasons to establish this theory. On the contrary, it is much more reasonable to suppose that after the colostrum once disappears no further change takes place, and that the only difference between the human milk provided for an infant three weeks and one nine months old is in the quantity. My own analyses sup-

port this conclusion. It is therefore an error to increase the strength of an artificial food during the first six to nine months, and in the frequent infringement of this law lies the explanation of the many failures in bringing up infants by hand. The correctness of this view is supported by the fact that practical experience bears out the theory. In a great many cases I have pursued the plan with the most satisfactory results.

There can be no doubt that improvement in the artificial feeding of infants must come through the diffusion of knowledge of the composition of human and cow's milk, the latter being the basis of most of the foods used in the civilized world. Since it was first announced by me so many years ago that *human milk never contains more than about one per cent. of casein*, the weight of authoritative opinion seems to tend more and more in the direction of the acceptance of this proposition. Authorities are disposed to admit it as a fact that the casein in human milk is less in quantity than that in cow's milk, and in setting a standard of the average they place it at one and a half, or even at one per cent. Having done this, however, they will quote analyses estimating the amount of casein in human milk as high as three per cent., or even more. This inconsistency, as has been said, is because most of the published analyses of milk are obtained by estimating the amount of sugar by the copper test.

As has just been said, it is only by the diffusion of knowledge of the composition of human and of cow's milk, and, therefrom, the arrival at a general standard food for infants, that we can hope for any great advance in artificial feeding. So long as chemists and physicians continue to believe that human milk sometimes contains

three, and even four, per cent. of casein, a great obstruction stands in the way of progress. Since the publication of my book upon "Milk Analysis" in 1885, my results have been quoted in some form in most of the publications upon the subject. No one, however, seems to recognize the fact that the most important question connected with the whole subject is whether it is true that human milk *never* contains the large proportion of casein so commonly ascribed to it. This question must be settled, and should be settled as soon as possible.

At present many physicians are unwilling to give a new-born infant a food such as mine, but prefer to use condensed milk or something equally bad during the first few weeks. The reason for this is difficult to understand, unless it is because there has not yet been a very general acceptance of my proposition in regard to the small amount of casein invariably present in human milk, and that many still believe milk to be a fluid of unstable composition instead of being very constant in composition, as it really is. The administration of condensed milk, or of some other equally unsuitable food, to infants during the first month or six weeks, has been the cause of death of many babies, which, if differently fed, would have survived. No one has ever advanced any reasonable, much less sufficient, argument for this practice of using condensed milk during the first few weeks after birth, and experience shows it to be most mischievous.

The sterilization of milk has been vaunted very much in recent years. This process consists in heating the milk to such a temperature as to destroy germs. The degree of heat thought necessary is not fixed, and different authorities have given different directions for steril-

izing. Formerly, bottles containing the food were placed in water which was brought to the boiling-point, but latterly there seems to be a tendency to the general agreement that so high a temperature produces changes which render the milk less desirable as a food for young infants, if it is not put in a condition to be positively injurious. Less high temperature is used to effect what is called "Pasteurization." The advocates of this system say that the germs are destroyed, and that the nutritious and digestive qualities of the milk are unchanged.

As time goes on there is more and more heard of the damage done by the heating of milk, and many now oppose the system altogether. For my part I have never been an advocate of its use under ordinary circumstances. It certainly must alter the milk to be cooked, and sterilization is cooking, whether the heat applied be of high or only of moderate degree. It seems better and more natural to see that the milk is pure and free from all contaminations, in the first place, than to purify by sterilization a milk which is supposed to be contaminated, and then use it to feed babies. The field of usefulness of the process of sterilization is probably to be found in cases where it is impossible to secure pure milk, but as to using it as a matter of general application it is not to be recommended.

Great advances have been made in the artificial feeding of infants in the last twenty years. The proof that such is the case is to be found in the fact that now no treatise on children's diseases would be considered complete without an article on the subject, while twenty years ago none of the books contained such articles, and those that treated the question at all merely discussed it incidentally in a subsection of an article upon one of the dis-

eases of digestion. Another evidence of advance is that there is almost universal agreement in advising that cow's milk should always be diluted when used as a food for young infants. This seems to indicate that experience has taught the fact that the casein in pure cow's milk is more than young infants can digest. In my opinion time will show the explanation of this to be in the doctrine already enunciated with so much emphasis, that human milk *never* contains more than about one per cent. of casein.

During the past fourteen years I have had much experience in the use of my food. At first there generally was some difficulty with the nurses, who thought it too weak and that it contained a great deal too much lime-water, and they would often change it to suit their various fancies. More recently there seems to be less difficulty, and persons will use it without having any prejudice against it at the beginning, as was formerly so commonly the case. In the great majority of instances, where it has been fairly tried, this food has proved very successful.

In a brief paper like this, there cannot be given a full account of all that pertains to so vast a subject, and I have not attempted more than to sketch the guiding principles. In conclusion, it is only necessary to add that the result, after fourteen years' trial, has been to make me think my food is even better than I ventured to hope it would prove when the formula was originally published.

Read at the Meeting of the Philadelphia County Medical Society, April 8, 1896.